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THE DISTRIBUTION OF RUBUS SPECIES IN THE STATE OF HAWAII

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ABSTRACT

Two endemic and seven alien species of Rubus are established in Hawai'i, with one or more alien species on each of the major islands except Kaho'olawe and Ni'ihau. The alien species are all thorny, easily dispersed, and are considered capable of disrupting native ecosystems. Whereas the ranges of the native species are relatively static, most alien species are thought to be capable of further spread from their present distributions. Cultivars are freely imported for purchase by homeowners and gardeners; however, Hawai'i has no significant commercial production of any Rubus fruit.

1.0 INTRODUCTION

This report describes the ranges of all native and known naturalized alien species of Rubus in the state of Hawai'i as a preliminary part of the National Park Service's effort to control weedy Rubus species. Our objective is to map the current regional range of each species and to determine the altitudinal and rainfall limits that may be used to predict the environments in which each species might be able to grow. It is necessary to determine the current and potential ranges because alien species that are targeted with biological control agents may be sympatric with native species.

Data were obtained from data bases, limited new field surveys, and other sources. The distributions of the widespread species are mapped as ranges, with no attempt to delineate actual populations or to distinguish between suitable and unsuitable habitats within the range. The locations of alien species with only localized populations are described as accurately as possible. In most cases, it is unfeasible to present population density data; the data may be limited in other respects.

There are two endemic Rubus species in Hawai'i and seven naturalized alien species. Some or all of the alien species were intentionally imported for fruit production. The aliens are all thorny, all easily dispersed by animals, and all may have the the potential to disrupt native ecosystems. Blackberry (R. argutus), is listed as a noxious plant, and the yellow Himalayan raspberry, (R. ellipticus), is considered a pest in the forest (Smith 1985). These two species have been targeted for biological control by the National Park Service.

The two endemic species, R. hawaiiensis and R. macraei, are found only in native plant communities or their remnants. Their ranges have been reduced by alterations to the vegetation by humans and feral herbivores; otherwise, their ranges and populations appear to be reasonably static. Rubus macraei is rare, classified by the U.S. Fish and Wildlife Service as a "Category 2" species, meaning that it may be endangered, but more research is needed to determine its status (Federal Register 1990). On the other hand, most or all of the alien species have not yet reached their projected environmental limits and may expand their ranges. Some of the alien Rubus species in Hawai'i are described as early succession or seral species in their native ranges. Van Royen (1969) says all the Rubus in New Guinea, including R. rosifolius, are sun-loving species that invade forest openings and disappear following canopy closure. This status as seral species may lessen the potential impact of these invaders in mature communities. However, many of the alien R. ellipticus and R. rosifolius thrive in disturbed sites within closed canopy forests in Hawai'i.

Good morphological descriptions are given for most of the Rubus species in Hawai'i by Wagner et al. (1990). The reader is referred to that source for technical descriptions of these species. Some descriptive information is given here to augment that source.

2.0 METHODS

2.1 SOURCES OF INFORMATION

Existing data bases, informants, and observations by the authors were used to identify the

known populations of all Rubus spp. in the Hawaiian Islands. The data bases used are the U. S. Fish and Wildlife Service Forest Bird Survey (FWS-FBS) (Scott et al. 1986) and the herbarium labels from all the major herbaria in the state (Bishop Museum, National Tropical Botanical Garden, University of Hawai'i at Manoa, Hawai'i Volcanoes National Park, and Haleakala National Park). The TNC-NARS (1989) survey of the state's natural area reserves was also consulted.

The raw FWS-FBS data are in the form of plant species lists recorded at regular intervals along transects through the state's forests between 1976 and 1980. These transects provide an intensive data base for most of the native forests, even in remote and difficult terrain. Field biologists contacted as informants include, L. Cuddihy, J. Jacobi, (Hawai'i); J. Canfield, T. Flynn, K. Robinson, W. Takeuchi (Kaua'i); P. Connally, P. Connanat (Lana'i); R. Bartlett, P. Higashino, R. Hobdy, A. Medeiros (Maui); R. Hobdy, E. Misaki, T. Stack (Molokai); K. Robinson (Ni'ihau); H. Kikukawa, C. Lamoureux, J. Obata, S. Perlman (Oahu). J. Lau and S. Perlman supplied information from most or all of the islands. These sources may be able to provide more information on the distribution of Rubus spp. on request. While the contributions of these people have been indispensible to the production of this report, it was decided not to attribute sightings or other data to particular individuals. The authors synthesized all available information and take responsibility for the distributions reported here.

The authors conducted field surveys as necessary to confirm species' presence or absence and range boundaries in areas where available data were inconclusive. Phenology data, when given, are from herbarium labels.

2.2 MAPPING TECHNIQUES AND ANALYSES

All known locations of all Rubus species were marked on USGS base maps. Place names (from herbarium labels, etc.) were identified with the help of the "Reference Maps of the Islands of Hawai'i" series by James Bier, published by the University of Hawai'i. These topographic and reference maps are useful accessories to this report.

Each species' range was determined from the data points compiled on the base maps. The range boundaries were drawn based on these criteria:

1) Enclose all the known locations marked on the base maps. This is essentially an exercise of connecting the dots outlining each species' range. Disjunct sightings were mapped as outliers.

2) Occurrences at the highest and lowest elevations and highest and lowest median annual rainfall (DLNR 1986) were used to determine limits of the potential range. In regions with too few data points to substantiate presence or absence, these limits were used to construct distribution boundaries.

All rainfall measurements in this report are mm annual median rainfall, as interpolated from rainfall isohyet maps (DLNR 1986). Elevations are given in feet above sea level (feet are used because standard topographic base maps give contour intervals in feet).

3. Boundaries based on potential limits were modified when reliable information was available that the species did not occur in a portion of the potential range.

Maps showing the distribution of each species were thus compiled. These maps and the accompanying range descriptions show regional distributions of these species, and, in a few cases, the location of known isolated populations. It should not be implied that a species occurs within all habitats of its range.

3.0 FINDINGS

3.1 OVERVIEW

The two endemic species and then the seven alien species of Rubus that occur in the Hawaiian Islands are individually discussed below. First, a generalized formula is given that defines the

species' range on all islands, followed by a discussion of that species' distribution on each of the islands (Table 1).

There are no Rubus species on Ni'ihau (K. Robinson, pers. com.) or Kaho'olawe, no doubt due to the dryness of these islands. Both receive less than 1000 mm rainfall annually—near the minimum required by any of the treated species.

3.2 THE DISTRIBUTIONS OF NATIVE SPECIES

3.21 THE DISTRIBUTION OF RUBUS HAWAIIENSIS Gray - 'AKALA

This 'akala is by far the commoner of the two endemic Rubus species. Like many others of the genus, it produces biennial stems. In their first year, the unbranched stems, termed primocanes, do not flower. These are often deciduous and may or may not bear prickles. Short, flower-bearing lateral branches arise from these one year old stems in the spring of their second year. These lateral branches, or floricanes, have very sparses prickles, or none at all.

'Akala is a common element in the wet native forests on the mountain summits of Kaua'i, Moloka'i, and West Maui. On the high mountains of East Maui and Hawai'i, 'akala occurs in the wet forests on the mid-elevation slopes and in the subalpine scrub. The lower elevation limit of 2000 to 2400 ft. is in wet Metrosideros forests with rainfall of at least 1500 mm. In the submontane and montane rainforests it is widespread, but usually of low density, favoring canopy gaps and stream banks. Above the wet forests of the high islands, the range extends into subalpine scrub with rainfall above 750 mm (rainfall may be as low as 500 mm on north and west sides of Mauna Kea). 'Akala is most conspicuous as a community component in this subalpine scrub where it forms extensive thickets of robust plants. The upper elevation limit is 6000 to 9000 ft. (Figure 1).

This endemic species does not appear to reinvade non-native vegetation, but it will persist with remnants of native vegetation on the margins of pastures and fields and in gulches. It is in bloom from December through April. Mature fruit are present from March through November, with heaviest fruiting during June and July.

3.211 RUBUS HAWAIIENSIS ON HAWAI'I (FIGURE 3)

'Akala is widespread in the wet native forests and the subalpine scrub on the windward (northeast) side of the island. It occurs in the Kohala Mountains above 2000 ft. To the southeast of Kohala, it is found intermittently from Waipio Valley to Pa'auilo, because native forest in the Hamakua Forest Reserve is discontinuous, frequently interrupted by pastures and alien tree plantations. 'Akala is much more frequent, still farther southeast, in the Hilo and Waiakea Forest Reserves, extending from the Mauna Kea slopes above Laupahoehoe to the Mauna Loa slopes as far as the Volcano Highway and the summit of Kilauea. Across this range, the lower elevation limit varies from the usual 2000 ft. to about 4000 ft. up-slope above Hilo. This shift may be linked to avoidance of an area with very high rainfall (up to 6000 mm).

'Akala is not common on Kilauea south of Volcano Highway in the Puna rainforests. Within Hawaii Volcanoes National Park, it has been collected at Pu'u Huluhulu near Mauna Ulu, at scattered locations along the Mauna Loa Strip Road, and may occur at other favorable sites above 2000 ft. elevation.

The upper limit of this windward 'akala population is 7000 to 9000 ft. on Mauna Kea, where it grows in gulches and remnants of native vegetation within the extensive pastures that once were subalpine scrublands. 'Akala has been found at 7000 ft. on the west side of Mauna Kea near Pu'u La'au where the rainfall is barely 500 mm. 'Akala might occur in a very intermittent band of favorable sites around the north side of Mauna Kea at this elevation. In the Humu'ula Saddle, on the northeast flank of Mauna Loa, and extending over to the summit of Kilauea, the upper limit is depressed to about 6500 ft.,

probably because of the mostly unsuitable, young lava flows at higher elevations.

Another population of 'akala occurs on the windward southeast slope of Mauna Loa. Its lower limit is at above 3000 ft. where the Ka'u Forest Reserve begins above the sugarcane fields. It extends up the slope through the wet Metrosideros forests into the subalpine scrub to its upper limit near 7000 ft. Rainfall in this region is from 1000 to 3000 mm.

A third population of 'akala is found in the wet and mesic forests and the subalpine scrub of North and South Kona. On Hualalai, it occurs in a narrow band of adequate precipitation between 4000 and 6000 ft. Many of these plants have white flowers, rather than the more common pink or rose color. Above Kealakekua Bay on Mauna Loa, the band broadens to include the slopes between 2000 and 7000 ft., extending south to the Manuka Natural Area Reserve. Within this range the annual rainfall varies from about 2000 mm at the lower elevational limit to less than 750 mm at the upper limit.

3.212 RUBUS HAWAIIENSIS ON MAUI (FIGURE 6)

On the northern slope of Haleakala, 'akala ranges from the Makawao Forest Reserve near Olinda southeast to the east side of Kaupo Gap. FWS-FBS transect data clearly define this range within the native forest between 2500 and slightly above 7000 ft., showing a distinct elevational limit exists independent of rainfall. Rainfall in this range is between 2000 and 6000 mm. At the east end of the island, in the Hana Forest Reserve, the lower elevational limit is markedly higher, between 3000 and 4000 ft.

'Akala is abundant and robust in the Kula Forest Reserve on the western slope from 5000 to 7000 ft. where rainfall is 1000 mm and higher. This species' range continues from the Kula Forest Reserve on to the southern slope of Haleakala into the Kahikinui Forest Reserve where it exists in remnant patches of native vegetation above 5000 ft., above the 1000 mm rainfall isohyet, as far east as Wailaulau Gulch in Manawainui.

On West Maui, 'akala occurs from 2500 ft. to about 5500 ft. near the summit of Pu'u Kukui. The species' range is not well documented except along the Pu'u Kukui Trail; however, it is reported to occur throughout the central core of the West Maui mountains above 2500 ft., especially in gulches and at the heads of the valleys.

3.213 RUBUS HAWAIIENSIS ON MOLOKA'I (FIGURE 9)

'Akala occurs in much of the forest reserve above 3000 ft. on Moloka'i. Its presence is well documented from Kaluahauoni to Kamakou; it is reported to grow in the native forest above 3000 ft. east of Kamakou, as well. The range of 'akala extends from slightly below the 2000 mm isohyet into Moloka'i's rainiest area, above the 4000 mm isohyet.

No 'akala occurs in West Moloka'i, all of which is well below 3000 ft. and is arid.

3.214 RUBUS HAWAIIENSIS ON O'AHU

'Akala does not naturally occur on O'ahu. Rootstock of 'akala from Kona, Hawai'i, was planted on Ka'ala in the Wai'anae range (4020 ft. elevation, 2000 mm rainfall) in 1933 by W. T. Pope (documented by notations on H. St. John's specimens 20130 and 22271 BISH). This population persisted at least until 1946, but apparently no longer exists, since it is not listed in the TNC-NARS (1989) Survey of Ka'ala nor have biologists visiting the area seen it in recent years.

3.215 RUBUS HAWAIIENSIS ON KAUA'I (FIGURE 12)

'Akala occurs in the understory of wet Metrosideros forests on the Alaka'i plateau and in wet gulches above approximately 3500 ft. elevation. Given this known distribution, we project its range to Namolokama, and other high rainfall mountains east of the Alaka'i Swamp, although it apparently has not been seen there.

All areas above 3500 ft. on Kaua'i receive more than 2000 mm rainfall annually.

3.22 THE DISTRIBUTION OF RUBUS MACRAEI Gray - 'AKALA

This endemic species shares the common name, 'akala, with R. hawaiiensis. Rubus macraei is a trailing shrub that otherwise resembles the erect-growing R. hawaiiensis. Rubus macraei generally grows in a narrow elevational belt between 5000 and 7200 ft. on Hawai'i and Maui (Figure 1). This species occurs at the upper edge of wet or mesic forests and in the lower reaches of the subalpine scrub where it is sympatric with R. hawaiiensis. Rubus macraei blooms throughout the year and fruits July through September.

3.221 RUBUS MACRAEI ON HAWAI'I (FIGURE 3)

Two major populations are known on Mauna Loa and one on Hualalai, all three between about 5000 and 6500 ft. with rainfall between about 750 and 3000 mm. On Mauna Loa, R. macraei is well known in kipuka at this elevation from Saddle Road south to the Mauna Loa Strip, and around Yee Hop Ranch in South Kona. One collection has also been made at 6200 ft. on the southeast slope of Mauna Loa, in Ka'u. This isolated sighting raises the possibility of a sparse distribution ringing the remote, little-visited southeast and southwest slopes of Mauna Loa, perhaps extending to the population on Hualalai in North Kona.

Rubus macraei was collected at Pua Akala on the east slope of Mauna Kea in 1945. No recent sightings on Mauna Kea are known. Perhaps the severe impact of ranching activities in the suitable habitat on Mauna Kea has eliminated R. macraei from this part of its range. R. macraei has not been found in the Kohala Mountains which have only a small area above 5000 ft. elevation.

3.222 RUBUS MACRAEI ON MAUI (FIGURE 6)

Rubus macraei grows predominantly between 5000 and 7200 ft. on the northeast slopes of East Maui at treeline between the montane forest and the subalpine scrub as well as around bogs and other forest openings. This species' main range is from near Hosmer's Grove, across Ko'olau Gap, to the top of Kipahulu and Manawainui Valleys on the east side of Kaupo Gap, with a break in the distribution north of Hanakauhi. In the upper Hanawi watershed, R. macraei may extend downslope to 4000 ft. Within this range, the rainfall is between 2000 mm and about 5000 mm. In 1919 and 1920, C. N. Forbes made collections farther west near Ukulele Camp and on the south slope of Haleakala at Pu'u Ouli.

Rubus macraei does not occur on West Maui which has very little area above 5000 ft. elevation.

3.3 THE DISTRIBUTION OF ALIEN SPECIES

3.31 THE DISTRIBUTION OF RUBUS ARGUTUS Link - BLACKBERRY

Blackberry is recognized as invasive and disruptive, perhaps the most noxious of all the weedy Rubus species. It grows in many habitats, including native forests, plantation forests, and fields and pastures (Smith 1985). The common cultivation of domesticated blackberries is discussed in the section on cultivars.

In the Hawaiian Islands, reproductive populations occur between 2000 and 8000 ft. elevation (Figure 1). The few plants observed at lower elevations do not appear to flower. Rubus argutus tolerates rainfall extremes slightly lower than 1000 mm and nearly as high as 6000 mm. The architecture of blackberry plants appears to change with elevation. Those growing below 4000 ft., and those found beneath a forest canopy, produce long trailing or climbing primocanes with large glabrous leaves. Plants growing in the

open above 6500 ft. produce erect primocanes with smaller pubescent leaves and fruits clustered in subsessile panicles.

Blackberry in Hawai'i flowers from January through October with heaviest flowering during the spring. Fruit are most abundant in July, although fruit are occasionally found in fall and winter.

Until recently, the blackberry in Hawaii was widely known as R. penetrans L. H. Bailey. Other synonyms used in the past include R. koehnei H. Lev. and R. mauicola (Wagner et al. 1990).

3.311 RUBUS ARGUTUS ON HAWAI'I (FIGURE 4)

There are three major populations of blackberry on Hawai'i, one each on Mauna Kea, Mauna Loa-Kilauea, and Hualalai. The Mauna Kea population is between 4000 and over 6000 ft., occurring on the windward side at the top of the montane rain forest and into the subalpine scrubland, most of which has been converted to pasture. Blackberry may be found along the streams of the montane forest as low as 3500 ft. Rainfall in this range is 1500 to 4000 mm annually. To the south, this population reaches to the Saddle Road, with a few observations on the Mauna Loa side. It is possible that a sparse population of blackberry extends farther south and reaches the major Mauna Loa-Kilauea population. To the north, this population extends at least as far as the Keanakolu Cabin, Hamakua District. The pastures and forest fragments on the Mauna Kea slope north of Keanakolu were not surveyed by the Fish and Wildlife Service Forest Bird Survey. However, beyond the Keanakolu Cabin, there is no blackberry along the Keanakolu-Mana Road, and extensive surveys at the appropriate elevation above Pa'auilo and near Kalopa State Park have found no blackberry, even though the rainfall is ample.

The Mauna Loa population of blackberry is centered on the east and southeast slopes of Mauna Loa and around the summit of Kilauea. Rainfall within this range varies from no less than 1000 to about 4000 mm. Blackberry extends south from the wet northeast rim of Kilauea down along the Chain of Craters Road to about 3500 ft. From this lower limit on Chain of Craters Road, the population extends north to the Volcano Highway reaching down-slope to about 2500 ft. at Glenwood, and then northwest across the highway. The FWS-FBS found blackberry infesting the native forest of the Ola'a Forest Reserve and into the southern edge of the Pu'u Makaala Natural Area Reserve. As of 1990, blackberry has not been found within the Disappointment Road Complex of the Natural Area or near Stainback Highway. North of Kilauea, blackberry is abundant, and frequently picked, in the Volcano Village area, and in the Ola'a Tract of Hawaii Volcanoes National Park. Directly up-slope, northwest, blackberry is abundant along the Mauna Loa Strip Road to 5000 ft., and follows Powerline Road to about 6000 ft. Blackberry has an intermittent distribution southwest of Kilauea across drier slopes between 3000 and 5000 ft. into ranchland and the Ka'u Forest Reserve, as far as the vicinity of Wood Valley, Ka'u District.

On the southwest side of Hualalai directly above Kailua Bay, blackberry is naturalized between 2000 and 5000 ft. The rainfall in this area ranges between less than 1000 to over 1500 mm.

In the Kohala Pu'u O Umi Natural Area Reserve blackberry occurs around 3700 ft. where it was found in 5% of sampled stations (TNC-NARS 1989).

Outlier populations are known, reflecting the popularity of blackberry as a cultivated small fruit and its ability to naturalize. A population estimated at one-hundred flowering plants was seen in spring, 1991, along the Hawai'i Belt Road near the Pleasant Acres Subdivision of Kamuela, South Kohala District. Another outlier population at about 3000 ft. elevation, upslope from Waiohinu, Ka'u, is reported to have started from past settlement in the area (J. Caverly, pers. com.), and was detected as a naturalized population by the Fish and Wildlife Forest Bird Survey. Other outlying groups of plants at 600

ft. elevation near Kurtistown, Puna, and in Hilo at 50 ft. elevation are far below the usual lower elevational limit. These plants have not been seen to flower.

3.312 RUBUS ARGUTUS ON MAUI (FIGURE 7)

Blackberry is widespread on the west side of Haleakala between 2000 and 7000 ft., growing in leeward areas with somewhat less than 1000 mm rainfall, and in areas with up to 6000 mm in the north. In the south, blackberry is in pastures from Ulupalakua and Pu'u Ouli to the Haleakala Highway at elevations below 6000 ft. (J. Powley, pers. com.). Low rainfall may impose a lower limit near 3000 ft. Blackberry is not found in the Kula Forest Reserve above these infested pastures, except a local population at Polipoli. Blackberry is also absent from most of the south slope, i.e., the Kahikinui Forest Reserve, except between and near Pu'u Pane and Manukani, and Pu'u Ouli northward. This west slope infestation continues north and east from the Haleakala Highway to Pu'u Lu'au and up to the west side of Ko'olau Gap. Blackberry in Ko'olau Gap appears to be limited to the extreme west side. The range of blackberry extends down-slope to the vicinity of Ulalena, in the Ko'olau Forest Reserve, at 2000 ft.

Another extensive infestation on the northeast slope of Haleakala occurs east of Ko'olau Gap from above 8300 ft. on Hanakauhi and Kalapawili down-slope to about 3000 ft. Some blackberry has been reported along Koukouai Stream in Kipahulu Valley and may occur elsewhere in Kipahulu. An outlying population occurs in the pasture near Paliku Cabin in Haleakala Crater. Blackberry is notably absent in the Hana Forest Reserve, and Waihoi Valley.

On West Maui, blackberry is localized near Kaulalewelewe Peak. It was probably introduced to West Maui from plantings at Haela'au Cabin at the head of the Pu'u Kukui Trail on Honokowai Ridge. Blackberry grows between 2400 and 4500 ft. on this ridge, with the heaviest infestation below 3250 ft. It is also found to the southwest in Honokowai Valley and on the next ridge across the valley between about 3200 and 3700 ft. This latter location is within the Honokowai section of the West Maui Natural Area Reserve (TNC-NARS 1989).

3.313 RUBUS ARGUTUS ON MOLOKA'I (FIGURE 10)

On Moloka'i, blackberry infestation is localized in the Molokai Forest Reserve along the Maunahui Road around Kikiakala. A number of outlying patches are also known in a line between Kikiakala and Lehuula. The known populations are between 2500 and 4000 ft. in a region with about 2500 to 4000 mm rainfall. In this area, blackberry is growing under plantation forests and in native montane rainforest. Noting that all the known populations are on roads or jeep trails suggests that either blackberry propagules are being carried along the road, or that in this rugged terrain only populations on roads are observed. The latter alternative points to the possibility that the blackberry infestation in the forest reserve is more widespread and dense than is now known.

3.314 RUBUS ARGUTUS ON O'AHU (FIGURE 11)

Blackberry grows in the nortwest Wai'anae Range above about 1500 ft. It is noted from Mt. Ka'ala, Makaha Valley, and between Makaha and Wai'anae Kai where it forms thickets. It occurs from Ka'ala south to Kalena, and east to the Schofield firebreak road. It is abundant in the Hale'au'au Gulch area. Apparently, it is absent from the Wai'anae Range south of Kolekole Pass and from the Ko'olau Range. Its distribution approximately fills the area above the 1500 mm rainfall isohyet. Blackberry has been actively controlled by volunteers in Ka'ala Natural Area Reserve.

3.315 RUBUS ARGUTUS ON KAUA'I (FIGURE 13)

Blackberry forms dense thickets in the Koke'e region between roughly 2500 and 4000

ft. Along the road to Koke'e blackberry becomes noticeable at approximately 2900 ft. elevation, and is dense in many valleys at slightly higher elevations. Along the Awa'awapuhi Trail, blackberry is found at 2600 ft. and higher. It occurs in the vicinity of Wai'alae Cabin and all along Kohua Ridge. Based on FWS-FBS information and field experts, this species has not penetrated the central Alaka'i. It is apparently absent from Haupu. It is known from Makaleha and may be in other mountains east of the Alaka'i.

Its distribution increased considerably following forest opening by Hurricane Iwa in 1982. It can readily be seen along the Pihea Trail that the parts of the forest that did not suffer hurricane damage are without blackberry, while it forms dense thickets in canopy gaps created by tree falls. Logging and other disturbances in Koke'e have also provided habitat for the species.

Blackberry is also found in the valleys of the Na Pali Coast, growing along the main streambeds in Hanakoa, Honopu, Nualolo Aina, Awa'awapuhi, and Miloli'i valleys.

3.32 THE DISTRIBUTION OF RUBUS DISCOLOR Weihe & Nees

This species is incidentally mentioned by Wagner et al. (1990), citing its occurrence at one location on Maui and one on O'ahu. Plants found growing at the Maui location conform to their description in all respects except that leaves commonly have five leaflets rather than three. Two other small populations of a Rubus species resembling R. discolor have been identified during this survey, one on Hawai'i and one on Maui. All of these occurrences are at sites with more than 1500 mm of rainfall between 2000 and 4000 ft. elevation (Figure 2).

3.321 RUBUS DISCOLOR ON HAWAI'I (FIGURE 4)

A population of fruiting Rubus that resembles R. discolor in its trailing growth form, silver underside of leaves, and light pink flower occupies a well-grazed pasture and adjacent roadside near Pohakea, Hamakua. These plants can be seen on the down-hill side of Manienie Road, a short distance east of Manienie Gulch near Pohakea at about 2000 ft. with about 1700 mm of rainfall. No other specimens are known from this island and no explanation of this occurrence is known. The site is within 2 miles of the Pa'auilo Agriculture Experiment Station where small fruits, including R. glaucus and R. niveus f. A, have been grown.

3.322 RUBUS DISCOLOR ON MAUI (FIGURE 7)

This species is well known from a single location on Maui. Rubus discolor was planted some time in the past on West Maui on Kaulalewlewe peak, at a cabin called "Haela'au," that is owned by the Maui Land and Pineapple Company. Haela'au, at the head of the Pu'u Kukui Trail, is 2980 ft. above sea level, where the rainfall is about 3500 mm. Rubus discolor is common in the grassy, somewhat overgrown, yard of the cabin where it grows intermingled with R. argutus. Rubus discolor was in flower (pink) and fruit (black) on September 11, 1989. An extensive search found no R. discolor outside the yard of Haela'au Cabin or on the Pu'u Kukui Trail; apparently, it is not spreading into the surrounding vegetation. In November 1989, volunteers under the direction of Maui Land and Pineapple Co. personnel pulled and burned the R. discolor found at this location. The site will be monitored by Maui Land and Pineapple Co.

Another population of Rubus that resembles R. discolor in the white lower surface of leaves and creeping habit, is established on East Maui near the Olinda Reservoir at 4000 ft.

3.323 RUBUS DISCOLOR ON O'AHU (FIGURE 11)

This species occurs in a burned area along Lanipo Trail on Mau'umae Ridge in the Ko'olau Mountains. It is spreading locally by runners, and is patchily distributed over several acres along the ridge near a Casuarina grove within

0.25 mile of the watershed boundary. Rubus discolor may have become naturalized when the Casuarina were planted. This species may also occur on Wiliwilinui Ridge to the east.

3.33 THE DISTRIBUTION OF RUBUS ELLIPTICUS Sm. - HIMALAYAN RASPBERRY

This species is native to tropical and subtropical India, the Himalaya region, Bhutan, Pakistan, Sri Lanka, Burma, southwest China, and the Philippines (Hara and Williams 1979, Wagner et al. 1990). Its distribution in the Himalayas is reported to be "common around villages" and with elevational limits of 600-2300 m (Polunin and Stainton 1984). In the Hawaiian Islands, R. ellipticus has been reported only on the island of Hawai'i where it flourishes between 1800 and 5100 ft. in an area with 2000 to 5000 mm rainfall (Figure 2). In Hawai'i, R. ellipticus blooms throughout the year and fruits in the fall.

3.331 RUBUS ELLIPTICUS ON HAWAI'I (FIGURE 5)

Rubus ellipticus is best known from a major infestation around the farm lots on Wright Road near the town of Volcano and around the summit of Kilauea (Figure 5.H). From Volcano and the east side of the Kilauea Caldera, it extends downslope to 1800 ft. and up-slope to about 4000 ft. at Kipuka Puaulu in Hawaii Volcanoes National Park. From this line, R. ellipticus has spread northeast through the Ola'a Tract of the national park, the Ola'a Forest Reserve and the Pu'u Maka'ala Natural Area Reserve to Stainback Highway. Clumps are scattered along Stainback Highway between 1800 and 5100 ft. elevation. The rainfall throughout this range is from about 2000 to 4000 mm.

Sightings of R. ellipticus have not been reported in the Upper Waiakea Forest Reserve north of Stainback Highway, nor was it seen in the vicinity of Tree Planting Road (approximately 3000 ft. elevation between Stainback Highway and Saddle Road) when the southern end of this road was well-surveyed in 1989-90. However, sightings in 1991 of this species along Saddle Road at 4600 ft. (mile-marker 18) and just south of Saddle Road at 1960 ft. elevation along Ola'a Flume Road, raise the possibility that R. ellipticus may also be establishsed in the Upper Waiakea Forest Reserve.

Rubus ellipticus was recorded at a single station in the Hilo Forest Reserve north of Hilo by the FWS-FBS at 2100 ft. elevation, west and up-slope of Papaikou. Another out-lying population of this species was noted at one station at 3600 ft. elevation along Blair Road in the Laupahoehoe Natural Area Reserve (TNC--NARS 1989). Wagner et al. (1990) describe R. ellipticus as naturalized at Laupahoehoe, North Hilo; however, we believe its distribution is highly localized and infrequent in North Hilo.

3.34 THE DISTRIBUTION OF RUBUS GLAUCUS Benth. - RASPBERRY

Rubus glaucus, cultivated in South and Central America, was introduced to University of Hawai'i at Manoa agricultural experimental farms on Hawai'i in the 1960's. The species was not subsequently exploited or propagated, but was allowed to escape from cultivation (Smith 1985; Tunnison et al., 1992). All known naturalized populations occur between 2000 and 4000 ft. elevation at locations with 1000 to 3000 mm annual rainfall (Figure 2).

Rubus glaucus is mentioned but not described by Wagner et al. (1990). The primocanes are erect and arching, light green with a glaucus bloom. The canes may be over 5 m long with tips touching the ground and rooting. Leaves have three leaflets that are white to very pale green on the lower surface. Petals are white. Fruit is 2 to 3 cm long, dark red to black when ripe, and is sweet and flavorful.

3.341 RUBUS GLAUCUS ON HAWAI'I (FIGURE 5)

Vigorous fruiting plants of R. glaucus can readily be found at the Volcano Agricultural Experimental Station, Puna District, and outside the

farm along Wright Road. By 1981 this species had spread about a mile to other agricultural lots in Volcano, and into the edge of the native forest of Ola'a Tract in Hawaii Volcanoes National Park (Anon., unpublished). It is not known if this population has spread further, but seems likely that it will. The elevation at this location is about 4000 ft. and the rainfall is close to 3000 mm.

Fruiting plants can also be found at about 2800 ft. elevation, in the Hamakua Agricultural Experimental Station above Pa'auilo, Hamakua. There are numerous clumps of R. glaucus in abandoned orchards near the upper boundary of the experimental farm, where it grows in close proximity with R. niveus f. A and R. rosifolius. Rubus glaucus has not been seen or reported in Hamakua outside the experimental farm. The rainfall at this experimental farm is about 2000 mm.

3.342 RUBUS GLAUCUS ON MAUI (FIGURE 7)

A previously unreported population of R. glaucus was found during this survey along the Haleakala Highway near the Sunrise Proteas Farm at 4000 ft. where the rainfall is about 1000 mm. Rubus glaucus grows together with R. niveus f. A at this site. The origin of this population is unknown, but this location is not far from the Kula Agricultural Experimental Station.

A single clump of Rubus sp. reported along the trail at Ainahou, Koolau Gap, may be R. glaucus.

3.35 THE DISTRIBUTION OF RUBUS NIVEUS Thunb.- HILL RASPBERRY

Wagner et al. (1990) recognized Rubus niveus from material collected on Maui and Hawai'i. In our field work we have located two distinct Rubus spp. to which this epithet has been applied, although Wagner et al. (1990) likely saw only one of these forms. One of these forms has deep pink or rose petals, five or seven leaflets, a terminal ovate leaflet, glaucous young stems that appear white, and purple/black fruit 1 to 1.5 cm long. We refer to this as form A. This appears to be the form that Wagner et al. (1990) saw and refer to as R. niveus. The other form, which we call form B, has light pink petals, nine to eleven leaflets, a terminal elliptic leaflet, and dark red to purple stems. Fruit characteristics are not known. Both have heavy prickles, robust canes, and a white tomentum on the underside of the leaves.

Wagner et al. (1990) describe R. niveus as an escaped cultivar. Their morphological description closely fits form A, which has sizeable populations surveyed and collected by one of us (GG) at Kula (not Polipoli), Maui, along the Haleakala Highway, on the Hamakua Coast of Hawai'i and the Kona and Ka'u districts of Hawai'i. The only known location of form B is the vicinity of Polipoli, Maui, where it has been collected by one of us (GG). There are no collections of R. niveus from Polipoli in the state's herbaria, so it is possible that Wagner et al. (1990) did not examine collections of form B. Since Polipoli is near Kula, there may be confusion between reports of form A at Kula and form B at Polipoli. We interpret Smith's (1985) reference to R. nivalis on Hawai'i and Maui to include populations of both form A and form B of R. niveus.

3.351 RUBUS NIVEUS ON HAWAI'I (FIGURE 5)

There is a heavy infestation of fruiting R. niveus, f. A, at the Hamakua Agricultural Experimental Station near Pa'auilo, Hamakua. Numerous and vigorous clumps form thickets in abandoned orchards near the upper boundary of the station. It appears that R. niveus has not invaded the margin of the forest plantation of introduced trees above the station. Large clumps have canes up to 3 cm in diameter that are red and non-glaucus and leaves that usually have 5 rather than 7 leaflets. Rubus glaucus and R. rosifolius grow on the same site as well. The elevation of this site is about 2800 ft. and annual rainfall is 1500 to 2000 mm.

Scattered clumps of fruiting plants of form A can also be found a few miles away, along Kuapahu Road, Pohakea, Hamakua, at about 2000 ft. with rainfall of about 2000 mm. A few plants have been seen in the town of Laupahoehoe and along the highway in Ka'awali'i Gulch in Hamakua, both locations are about 500 ft. elevation with at least 3000 mm annual rainfall. Figure 5 shows the possible distribution of this species in Hamakua drawn by enclosing these four sightings. The report of this species at Humu'ula (Smith 1985, Wagner et al. 1990) may refer to the Humu'ula ahupua'a near O'okala, Hamakua.

N. Krause collected R. niveus from cultivation in Opihihale, South Kona. A local resident reports that this species was widely distributed by Division of Forestry personnel and is now widespread in Kona (S. Greenwell, pers. com.). The extent of naturalization in this area has not been determined during this survey, but there is a well-known thicket along the highway opposite the entrance to Manuka State Park, Kau District (1800 ft. elevation), and a single clump near the highway at Kainaliu, South Kona District (1400 ft. elevation). It is reasonable to assume that there are other subpopulations in the South Kona and Kau Districts. The clump at Manuka State Park appears to have been sprayed with herbicide in the summer of 1990 and was of low vigor, but not dead. Annual rainfall at Manuka State Park is 1500 mm.

Rubus niveus was collected by R. Nagata at the refuse dump in Volcano, Puna (Wagner et al. 1990), but recent searches have not found it there.

3.352 RUBUS NIVEUS ON MAUI (FIGURE 7)

Populations of R. niveus, f. A, are found in pastures and waste places along Kelaulike Avenue, just above Keokea, and along the Haleakala Highway, in the vicinity of Sunrise Proteas Farm. In this range, between 3000 and 4000 ft., the rainfall is about 1000 mm. A single non-fertile individual that appears to be R. niveus f. A was found on the roadside between Haiku and Kuiaha in 'Ohi'a Gulch. This sighting raises the possibility that R. niveus f. A may be widely scattered on the west side of Haleakala.

The only known location of R. niveus form B in the Hawaiian Islands is on the western slope of Haleakala in the native subalpine scrub of the Kula Forest Reserve and in the pastures below the reserve. It can be seen along Waipoli Road, near Polipoli, at an elevation of about 6400 ft.; occasional plants occur as low as 3000 ft., near Waiohuli on the Kula Highway. Rainfall in this range is about 750-1000 mm. Specimens along Waipoli Road are very robust with dark red, non-glaucus, heavily armed canes. Flowers are small (8-10 mm) with deep pink petals; fruit have not been observed, but this species is spreading by vegetative reproduction.

3.36 THE DISTRIBUTION OF RUBUS ROSIFOLIUS Sm. - THIMBLEBERRY

This small raspberry of Asian origin was introduced to the Hawaiian Islands from Jamaica in the 1880's (Degener 1936). Its distribution throughout Hawai'i ranges from sea level to 6500 ft. and is generally found above the 1500 mm rainfall isohyet (Figure 1). In regions with rainfall as low as 1000 mm, thimbleberry may be found along water courses or in other favorable, wet microhabitats such as moist road-cuts. Within this wide range, thimbleberry is not limited by vegetation type. It invades native forests following disturbance, by pigs or other agents, and thrives as a common weed on roadsides, waste places, and gardens. Thimbleberry flowers and fruits throughout the year.

Plants that appear to be hybrids of R. hawaiiensis and R. rosifolius have been observed in the Ola'a Tract of Hawaii Volcanoes National Park by one of us (GG), and on Maui.

3.361 RUBUS ROSIFOLIUS ON HAWAI'I (FIGURE 4)

Rubus rosifolius is ubiquitous in disturbed vegetation from sea level to 5000 or 6000 ft. on

the windward side of Hawai'i. This population extends from Kohala in the north through Hamakua, south to Kilauea and following the Chain of Craters Road to the coast, then east to Cape Kumukahi. Low rainfall, presumably, prevents R. rosifolius from growing at these same elevations west of the Kilauea summit.

Thimbleberry occurs on the southeast flank of Mauna Loa between 1000 and 6200 ft., including the entire Ka'u Forest Reserve. This population is generally enclosed in the 1500 mm rainfall isohyet. The elevational distribution of thimbleberry is very similar in Kona where it appears above 1000 ft. wherever the rainfall is adequate, and the upper elevation limit wavers between 5000 and 6000 ft., in some places with a scant 1000 mm of rainfall. This West Hawai'i population extends from the slopes of Hualalai in the north to Manuka in the south, with outlying sightings slightly farther north at Pu'u Wa'awa'a.

3.362 RUBUS ROSIFOLIUS ON MAUI (FIGURE 7)

On East Maui, thimbleberry has a well defined upper elevation limit of about 5000 ft. and a minimum annual rainfall of 1000 mm. On the northern, windward, slope thimbleberry is found from near sea level to a maximum of 5000 ft. from Ulumalu east to Hana. In the eastern part of this range, the upper elevational limit descends to about 4000 ft. The range then continues from Hana to the east side of Kaupo Gap between sea level and 4000 ft. Thimbleberry is infrequent across the southern and western slopes of East Maui because of low rainfall. In these regions, the 1000 mm isohyet is high on the slope, near the upper elevation limit of thimbleberry, leaving, at most, a narrow band of suitable habitat.

The range limits are similar on West Maui. Thimbleberry is common in the watershed above 1750 ft. This species does not occur at the summit of Pu'u Kukui (5788 ft.), but has been recorded at 5410 ft. on the Pu'u Kukui Trail in an area above the 7000 mm isohyet. This is considered a population outlying the main range below 5000 ft. On the northern slopes of West Maui, thimbleberry grows in a few favored sites along the Kahekili Highway at about 800 ft., just above the 1000 mm isohyet. Thimbleberry is not found on the dry isthmus of central Maui.

Plants that appear to be hybrids of R. hawaiiensis and R. rosifolius have been observed.

3.363 RUBUS ROSIFOLIUS ON LANA'I (FIGURE 8)

Thimbleberry occurs patchily from as low as 1900 ft. and likely lower along watercourses, to Lana'ihale, the summit of the island at 3379 ft. Its distribution fits within the 1000 mm rainfall isohyet, apparently limited from occupying lower elevation sites by low rainfall. In the higher, wetter areas where it does occur, it appears that this species has not fulfilled its potential distribution or density.

Thimbleberry is the only Rubus species we observed on Lana'i. No other species are known from herbarium collections or by biologists familiar with the island.

3.364 RUBUS ROSIFOLIUS ON MOLOKA'I (FIGURE 10)

Thimbleberry is restricted to the forest reserve of East Moloka'i. Thimbleberry does not occur below the 1000 mm rainfall isohyet, but does extend into the wettest areas, above the 4000 mm isohyet. However, this species' distribution is eccentric with respect to rainfall, and with respect to elevation. Thimbleberry occurs close to sea level on the cliffs of northern, windward, side of East Moloka'i. On the other slopes of the eastern end of the island, the lower elevation limit is 1500 to 2000 ft. (Cliff Soares, pers. com.), roughly corresponding with the 2000 mm isohyet. At the far western end of the forest reserve, thimbleberry grows at 2100 ft., and above, in areas with as little as 1500 mm rainfall. On the southern side of East Moloka'i, thimbleberry occurs with low frequency above 3000 ft., extending from this elevation into the

wet, central part of the forest reserve and to the summit near Kamakou.

3.365 RUBUS ROSIFOLIUS ON OAH'U (FIGURE 11)

Thimbleberry occurs from near sea level on O'ahu's windward coast to the summits of the Ko'olau and Wai'anae ranges. It is not found near sea level along the Wai'anae coast but its presence in a wet area at Wahiawa Botanical Garden suggests that this species could extend across the central plateau in moist microhabitats. Thimbleberry on O'ahu requires a minimum of 1000 to 1500 mm of rainfall.

3.366 RUBUS ROSIFOLIUS ON KAUA'I (FIGURE 13)

Thimbleberry is found from near sea level on the north side of the island to over 4000 ft. on the Alaka'i Plateau. It was found at least sparingly along each of the FWS-FBS transects there. It is uncommon throughout the relatively intact Alaka'i montane rain forest, although it is found sparingly in disturbed sites along trails. It is found in all the windward valleys and in disturbed sites throughout the wet mountains of Kaua'i. It is absent where there is no disturbance.

Rubus rosifolius occurs at the western end of the Awa'awapuhi Trail at 2250 ft. with an annual rainfall of 1000 mm. It is absent along the lower, dry part of the Koke'e Road, but occurs at and above approximately 3000 ft which falls between the 1000 and 1500 mm isohyets.

3.37 THE DISTRIBUTION OF RUBUS SIEBOLDII Blume

This species is a native of Asia and has been cultivated in Hawai'i. It is known to occur only on Kaua'i (Figure 2).

3.371 RUBUS SIEBOLDII ON KAUA'I (FIGURE 13)

This robust, thorny raspberry is known from at least three areas on Kaua'i: Lawa'i at approximately 650 ft., Kilauea at 325 ft., and near Kalihiwai Reservoir at 400 ft. These sites receive about 1500 mm annual rainfall. This species has not become naturalized in any vegetation dominated by native species, and has been actively controlled at these known sites.

3.4 CULTIVARS

USDA Extension Service reports that at this time there is no significant production of any Rubus fruit in Hawai'i (D. Ward, pers. com.). Nursery stock of Rubus species is freely imported into the state for use by homeowners and gardeners.

"Boysenberry," which may be a domesticated, thornless blackberry x raspberry hybrid, and other Rubus species are readily available for purchase. We have observed abandoned plants at 2000 ft. on Maui and Hawai'i which persist for some years, but do not seem to spread away from their original site. It has been observed that in some of this commercial stock, vegetative cuttings and root-tip regeneration produce thornless plants, but shoots from mechanically disturbed roots are thorny (L. Wheeler, pers. com.).

A persistent clump of a Rubus sp. was observed in the little-used Keanakolu Orchard at about 5300 ft. elevation in Hamakua, Hawai'i. These plants resemble the raspberry commonly cultivated in North America and known as "black-cap." This population did not seem to be spreading from the orchard into the neighboring vegetation.

Other abandoned patches of Rubus certainly exist in locations throughout the state of Hawai'i.

ACKNOWLEDGEMENTS

The information in this report is derived from previously assembled data bases and the knowledge of many biologists and land managers in the state of Hawai'i. We are greatly indebted to the U.S. Fish and Wildlife Service Forest Bird Survey, and especially to J. D. Jacobi, for providing extensive data concerning the distribution of Rubus spp. within the state's forests.

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Table 1.

Distribution of Rubus species by island. Abbreviations of island names: HA=Hawai'i, KA=Kaua'i, KH=Kaho'olawe, LA=Lana'i, MA=Maui, MO=Moloka'i, NI=Ni'ihau, OA=O'ahu. X denotes presence on island.

	ISLAND							
Species	HA	MA	KH	LA	MO	OA	KA	NI
Rubus hawaiiensis	X	X			X		X	
Rubus macraei	X	X						
Rubus argutus	X	X			X	X	X	
Rubus discolor	X	X				X		
Rubus ellipticus	X							
Rubus glaucus	X	X						
Rubus niveus f. A	X	X						
Rubus niveus f. B		X						
Rubus rosifolius	X	X		X	X	X	X	
Rubus sieboldii							X	

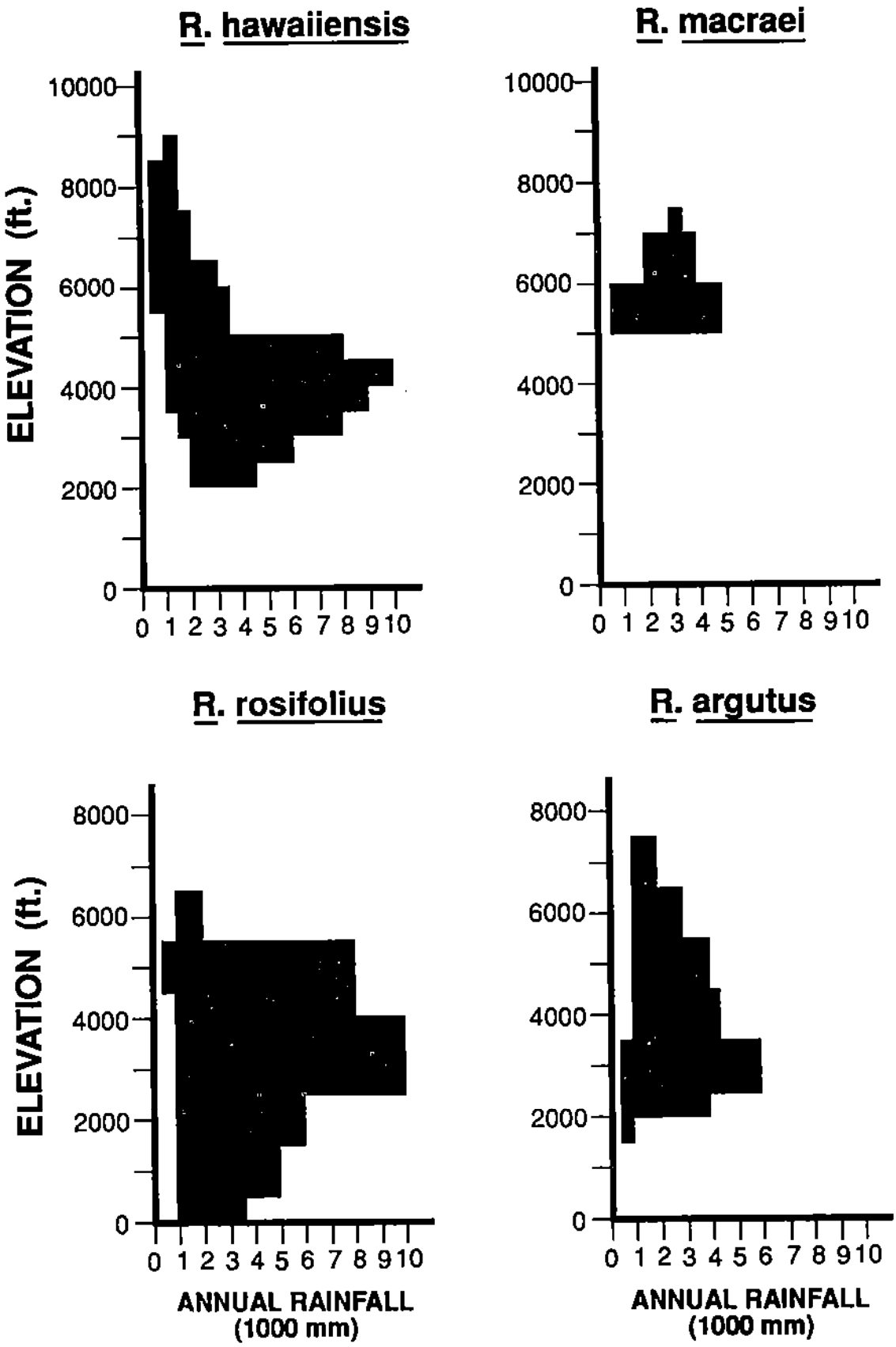


Figure 1. Diagramatic representation of the elevational and rainfall bounds of four Rubus spp. in the Hawaiian Islands. Elevation is in feet, median annual rainfall is in millimeters.

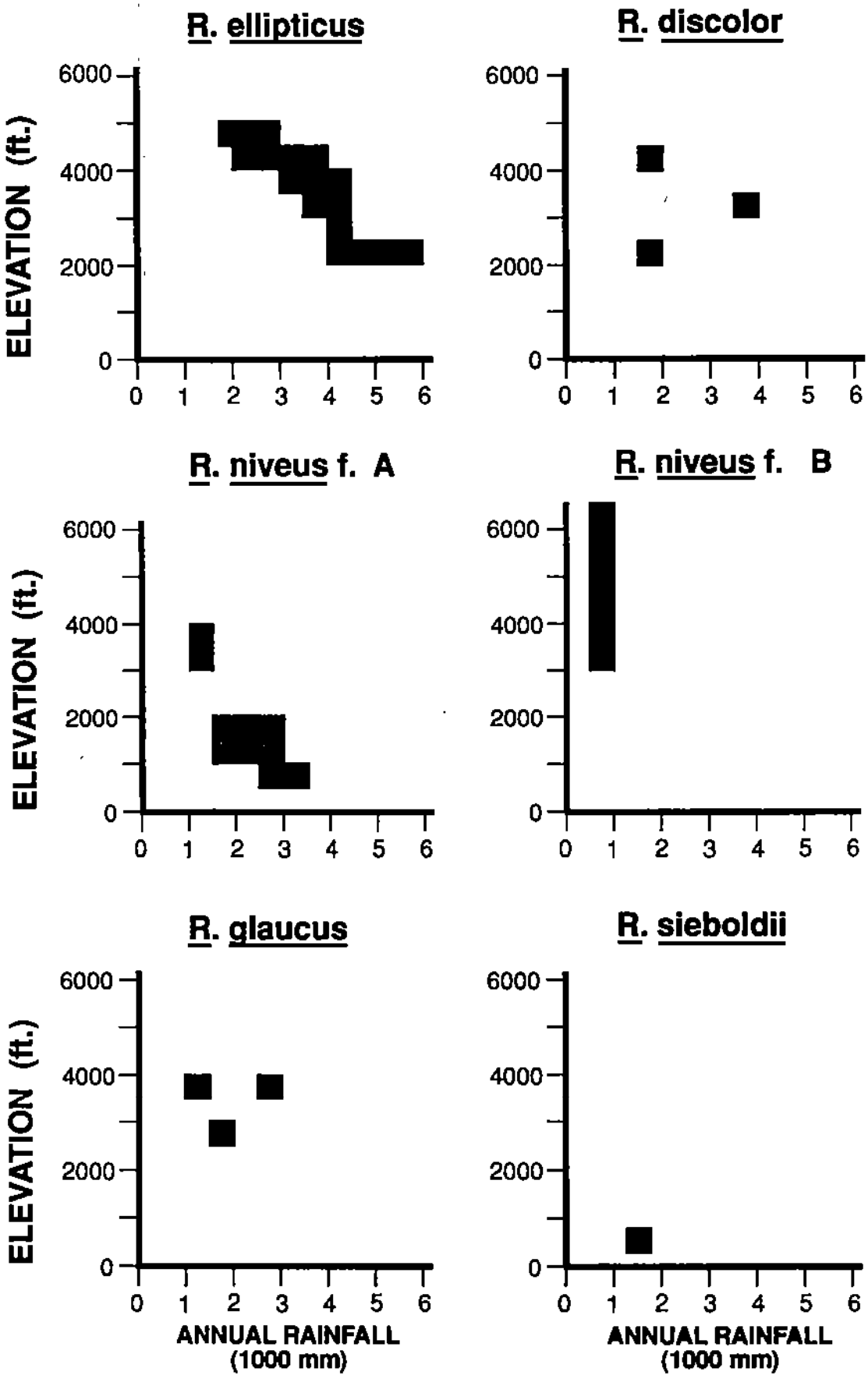


Figure 2. Diagramatic representation of the elevational and rainfall bounds of six Rubus spp. in the Hawaiian Islands.

Figure 3. The ranges of two endemic Rubus species, R. hawaiiensis and R. macraei, on the island of Hawai'i.

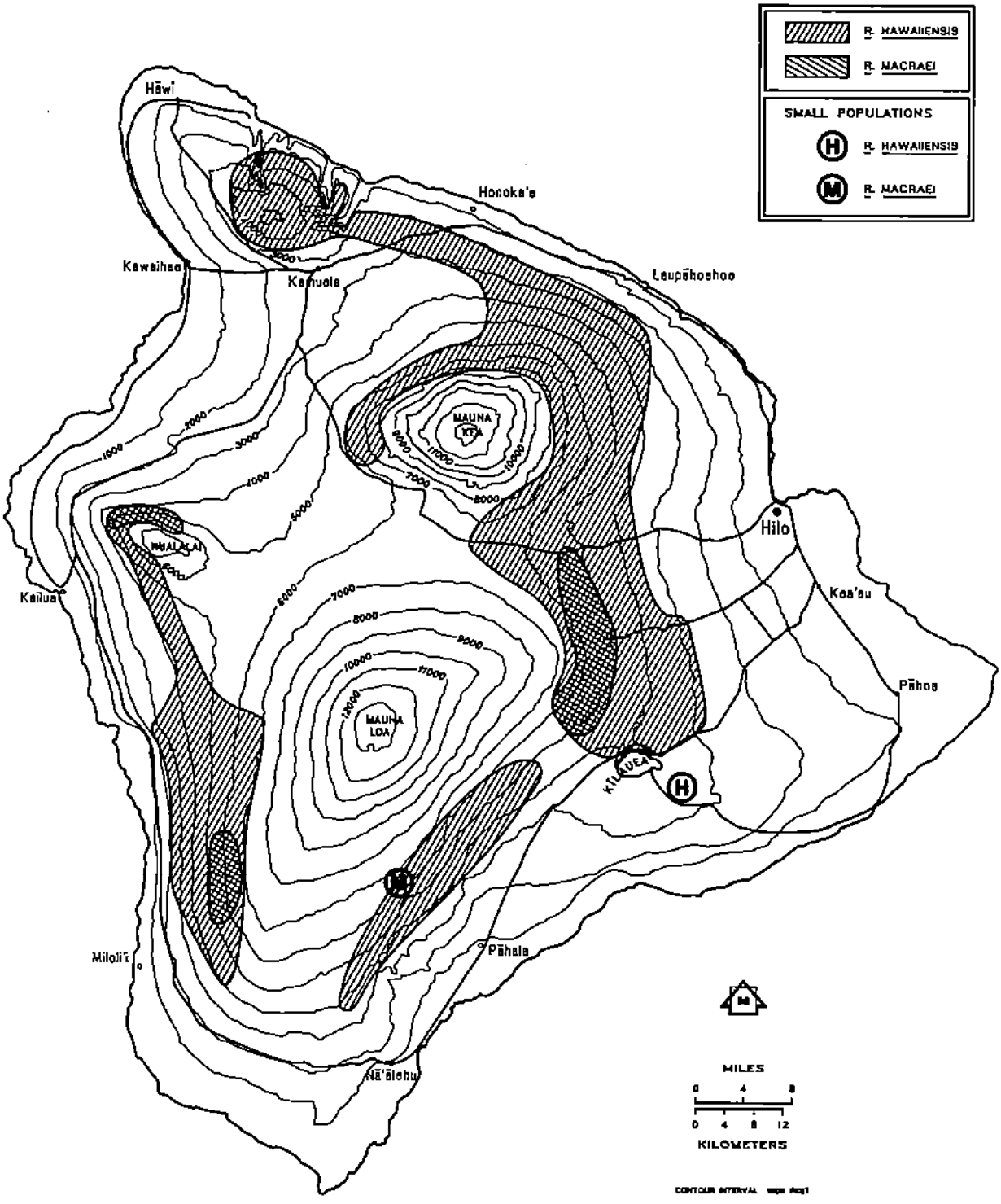


Figure 4. The ranges of two alien Rubus species, R. argutus and R. rosifolius, on the island of Hawai'i.

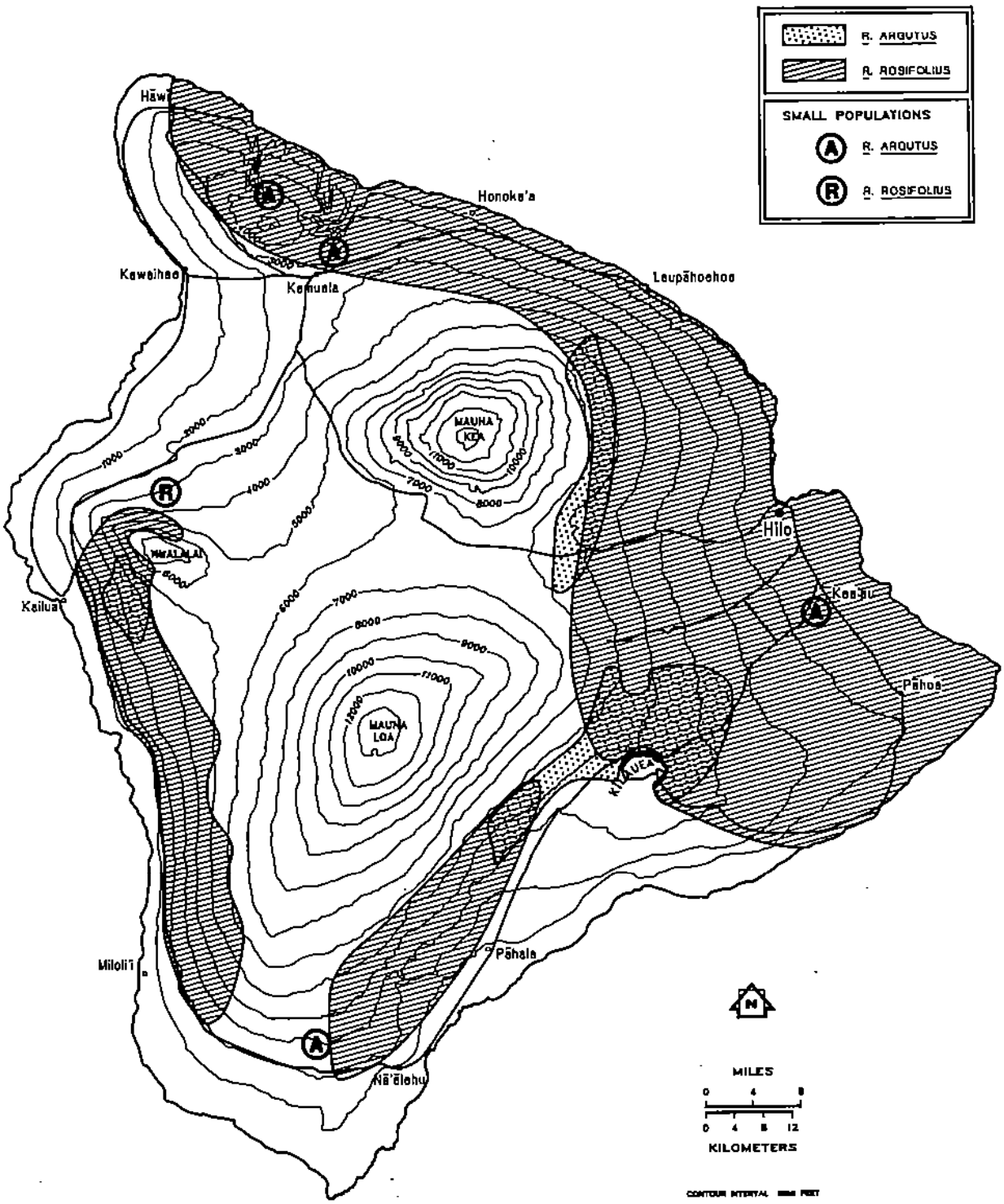
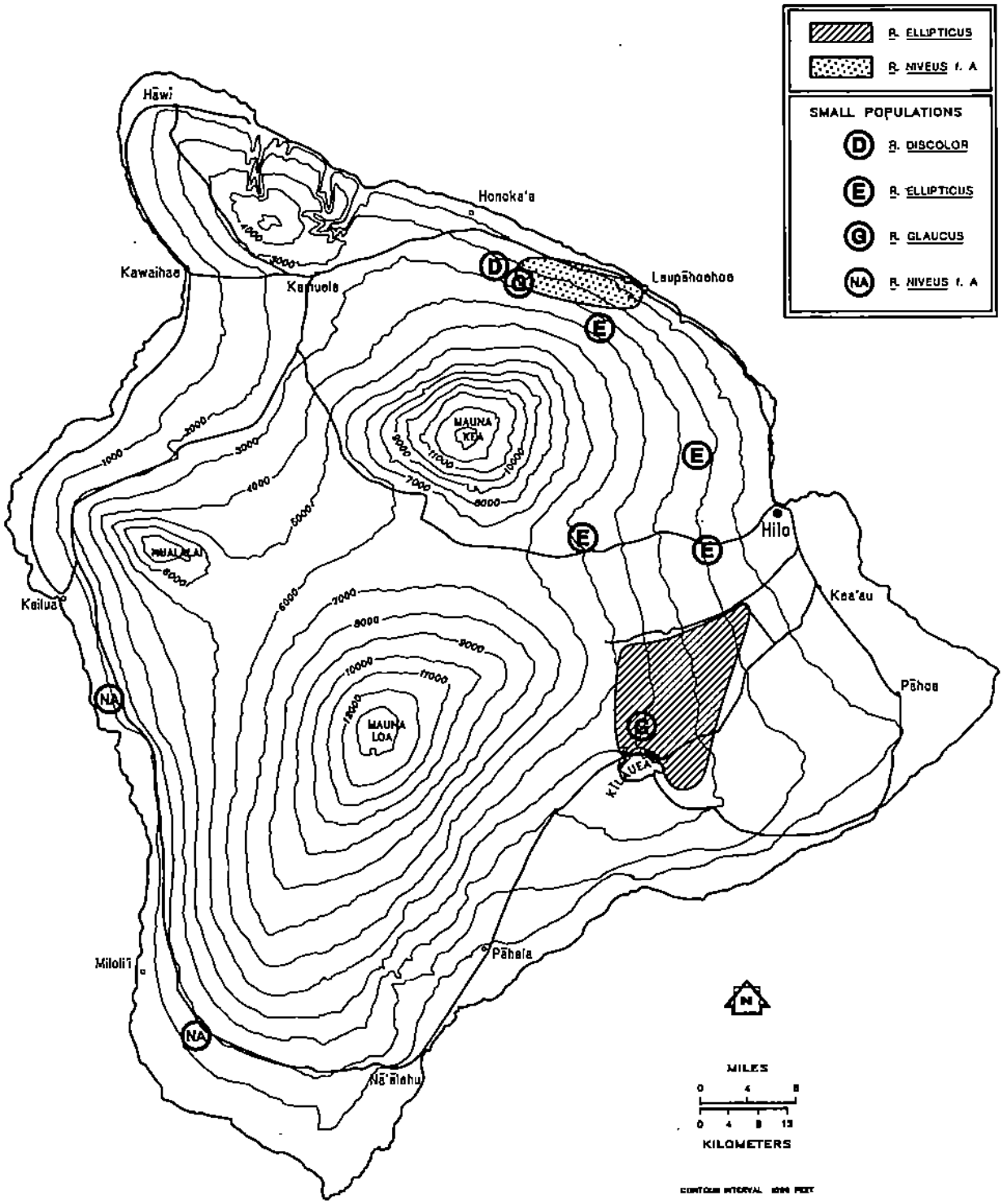


Figure 5. The ranges of four alien Rubus species, R. ellipticus, R. discolor, R. glaucus and R. niveus f. A, on the island of Hawai'i.



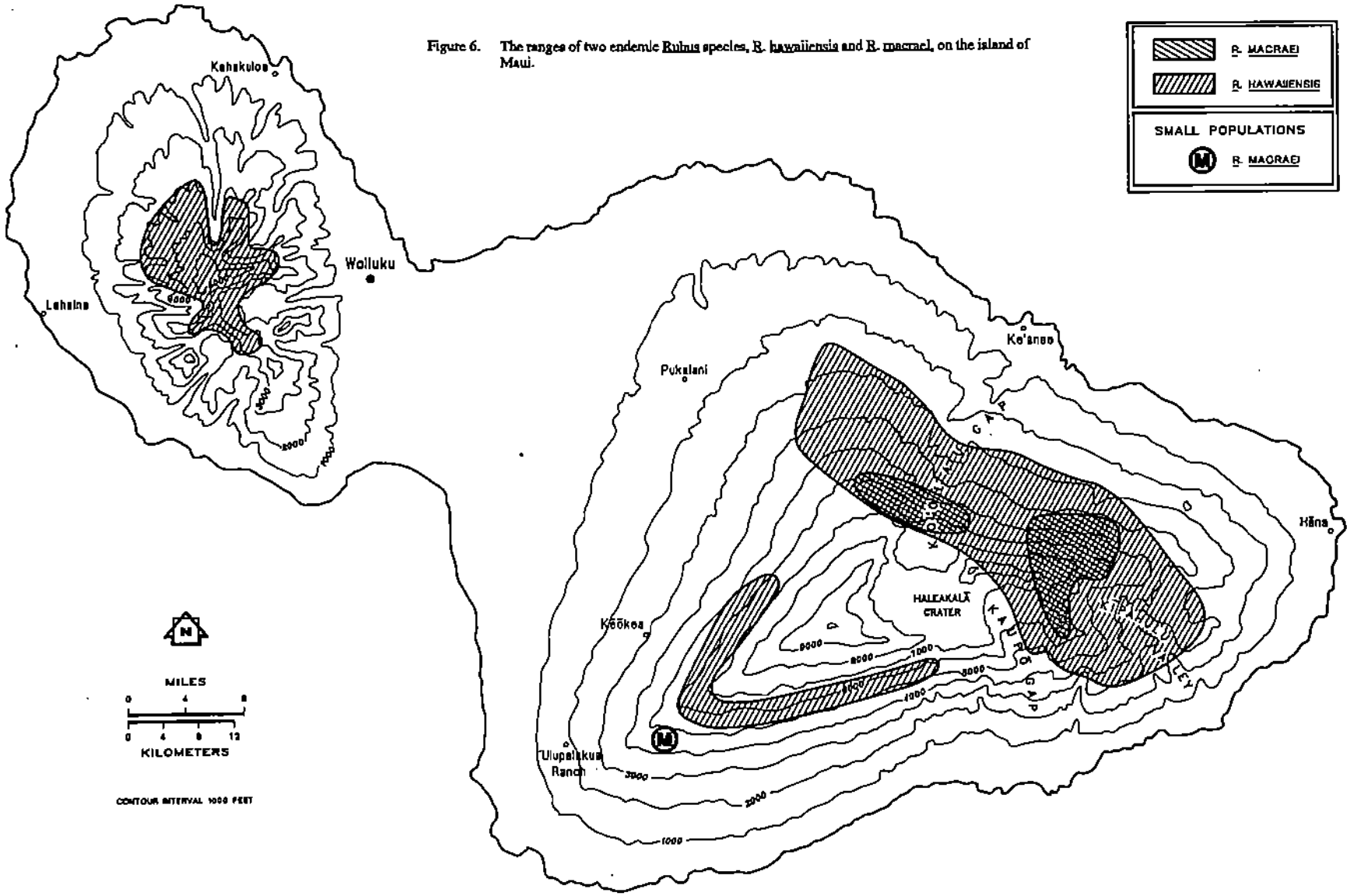


Figure 6. The ranges of two endemic Rubus species, R. hawaiiensis and R. macraei, on the island of Maui.

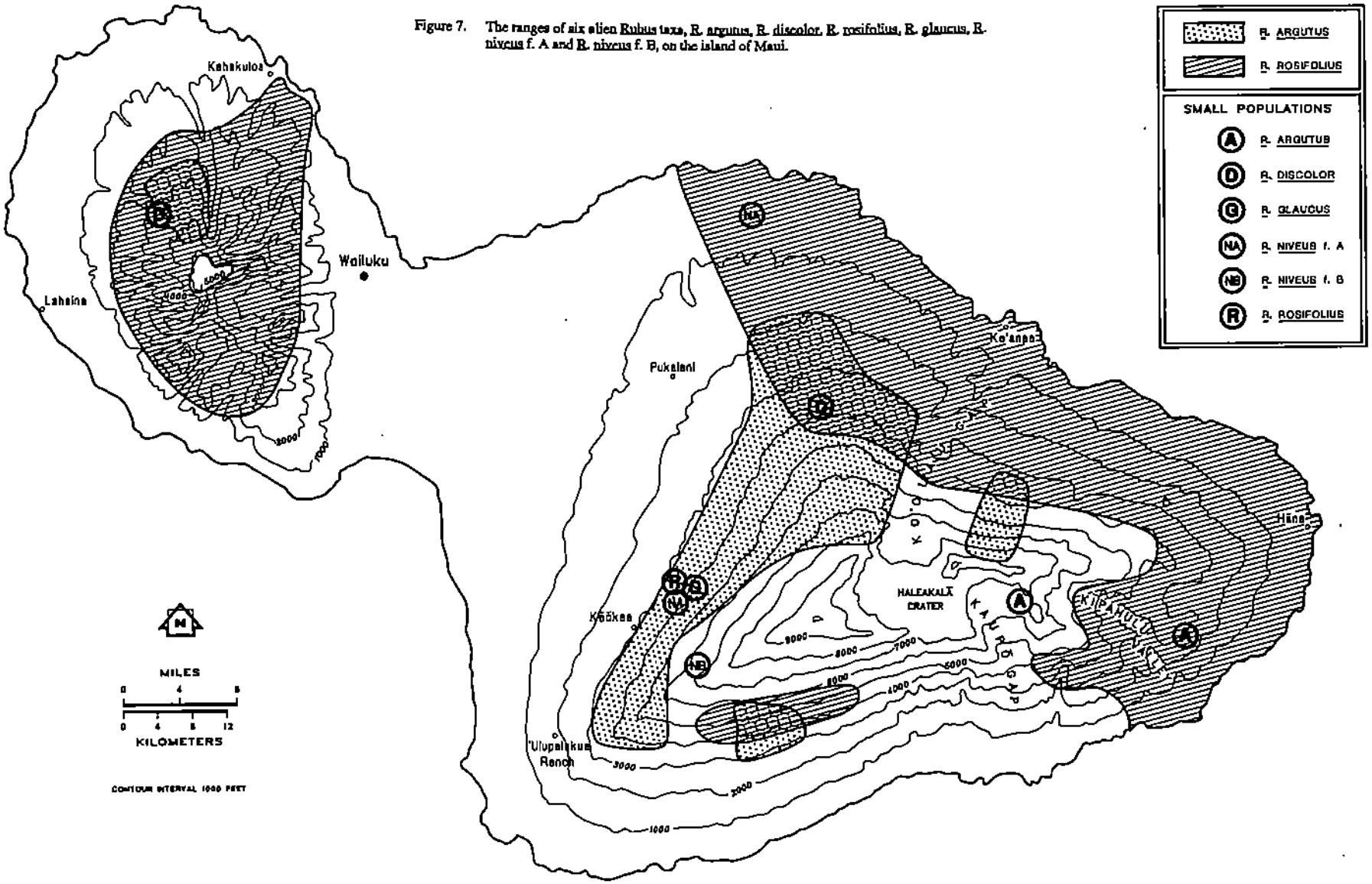


Figure 7. The ranges of six alien Rubus taxa, R. argutus, R. discolor, R. rosifolius, R. glaucus, R. niveus f. A and R. niveus f. B, on the island of Maui.

Figure 8. The range of the alien Rubus rosifolius on the island of Lana'i.

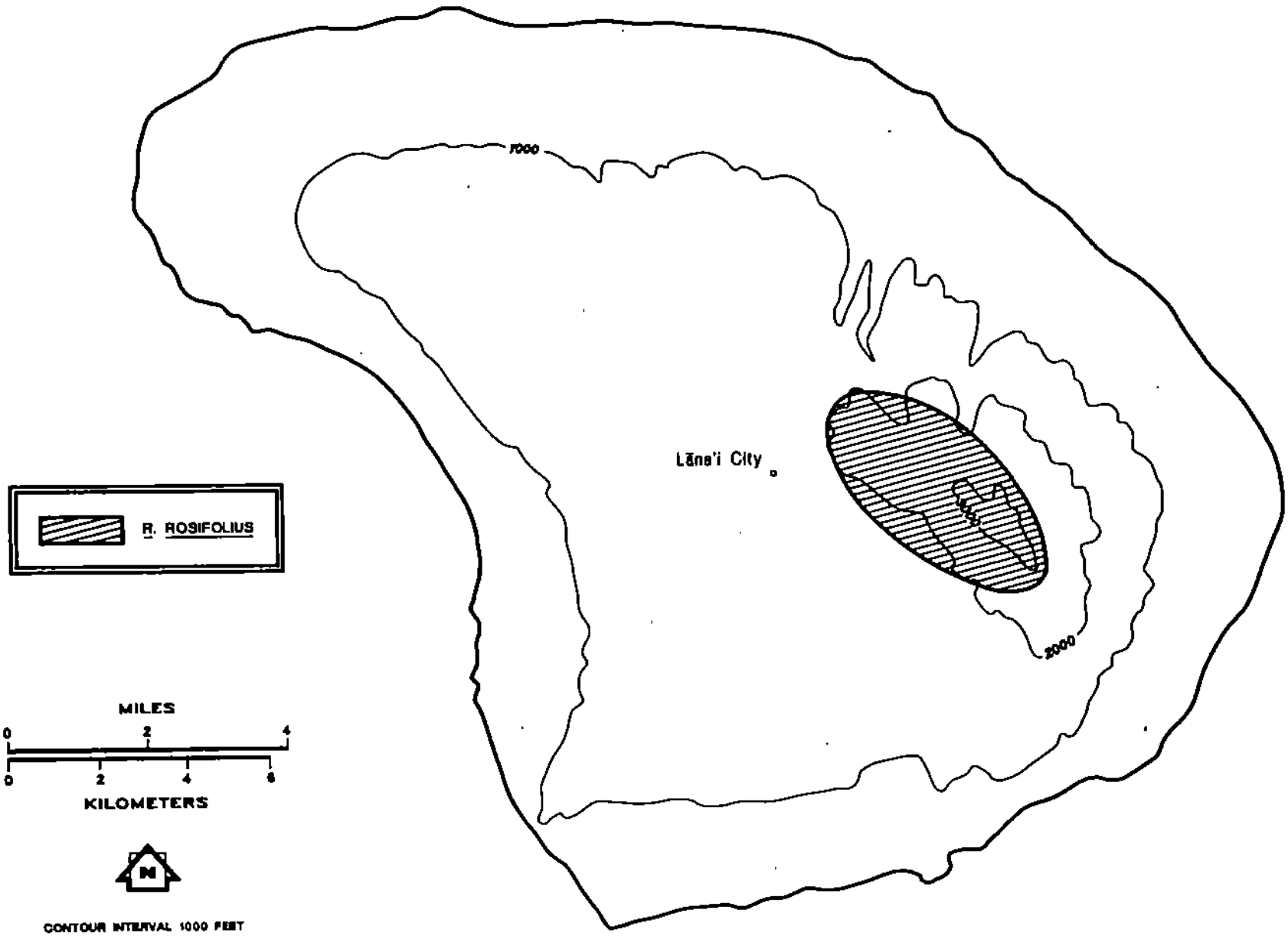


Figure 9. The range of the endemic Rubus hawaiiensis on the island of Moloka'i.

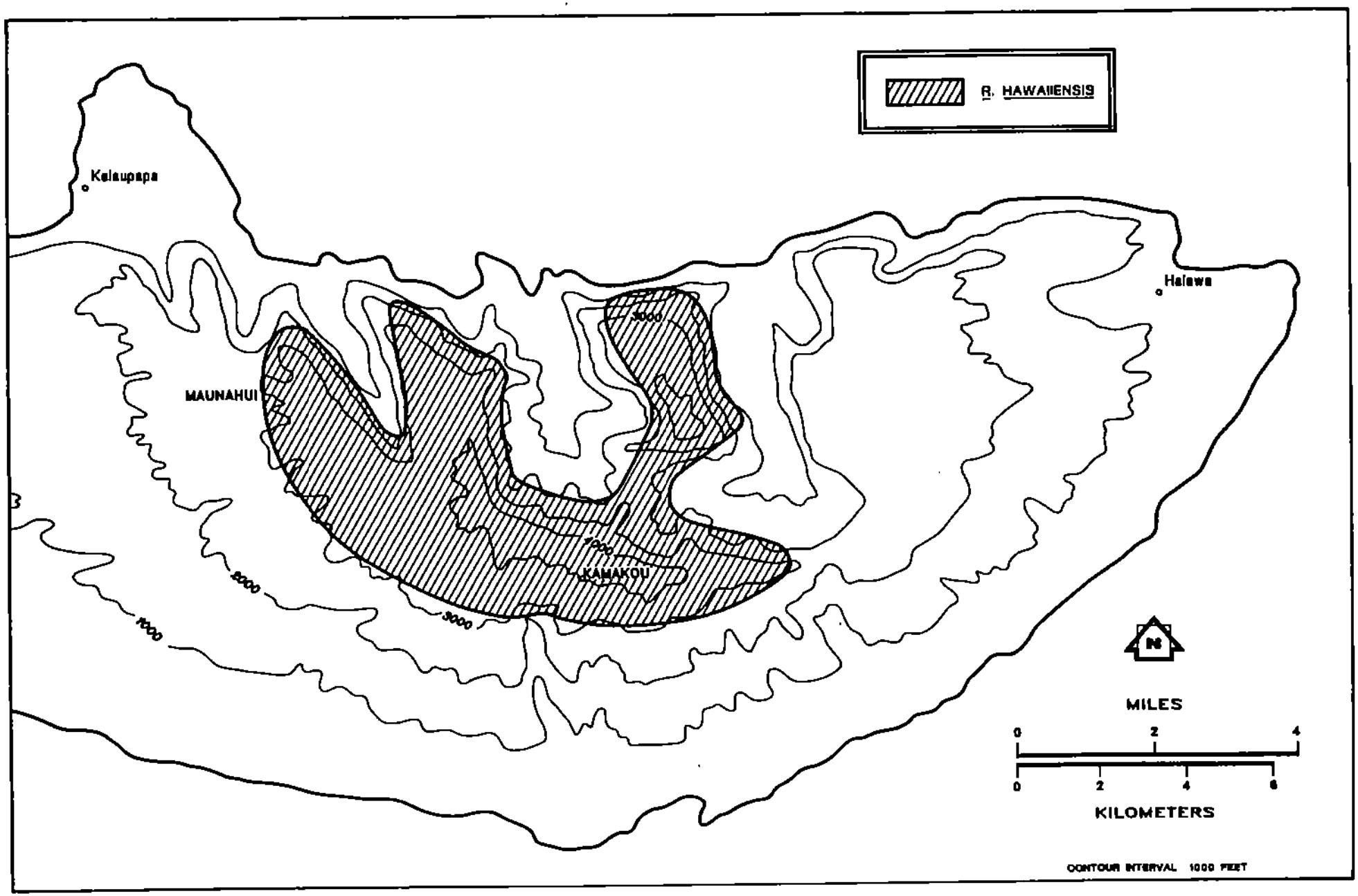


Figure 10. The ranges of two alien Rubus species, R. argutus and R. rosifolius, on the island of Moloka'i.

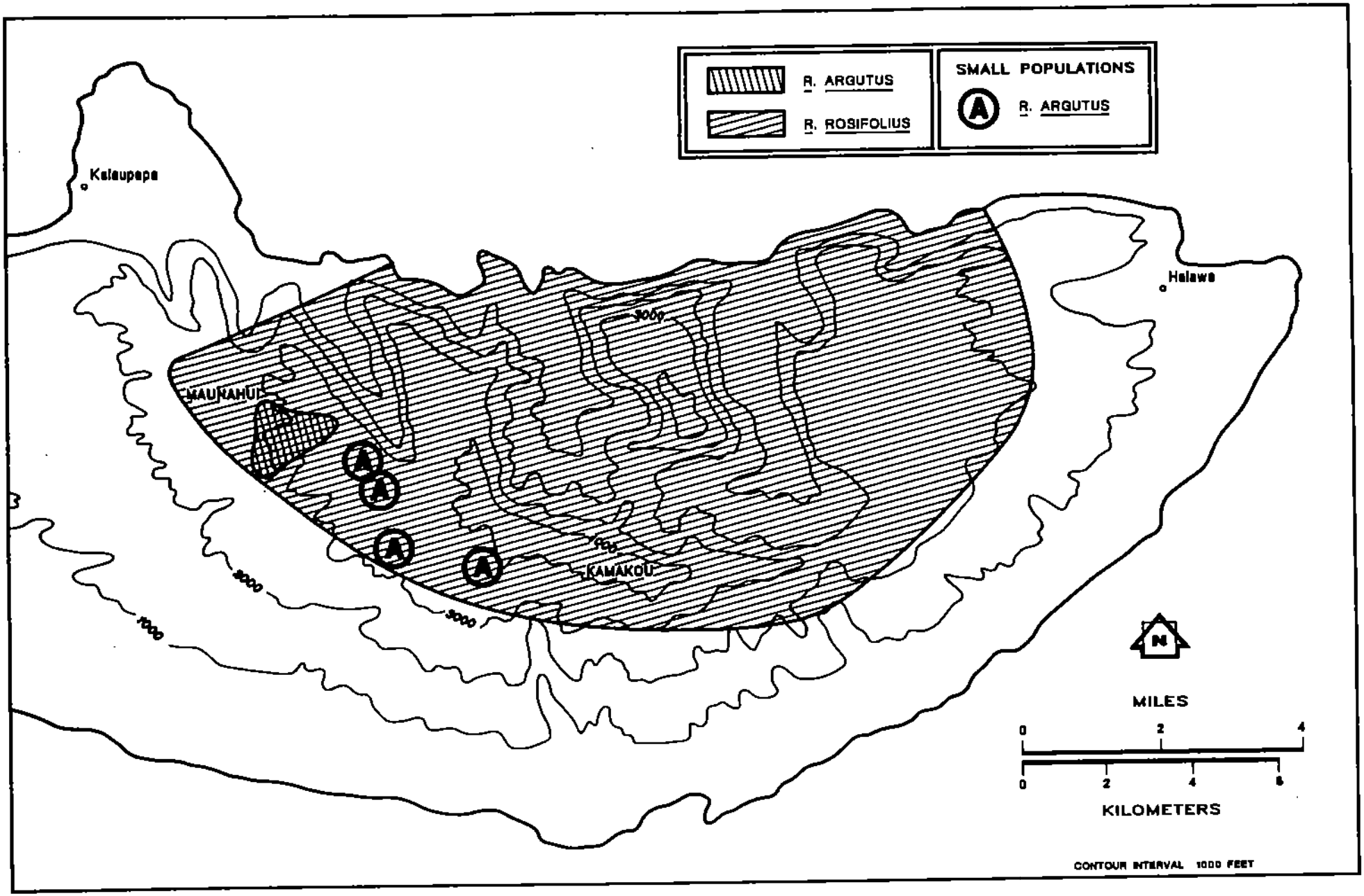


Figure 11. The ranges of three alien Rubus species, R. argutus, R. discolor and R. rosifolius, on the island of O'ahu.

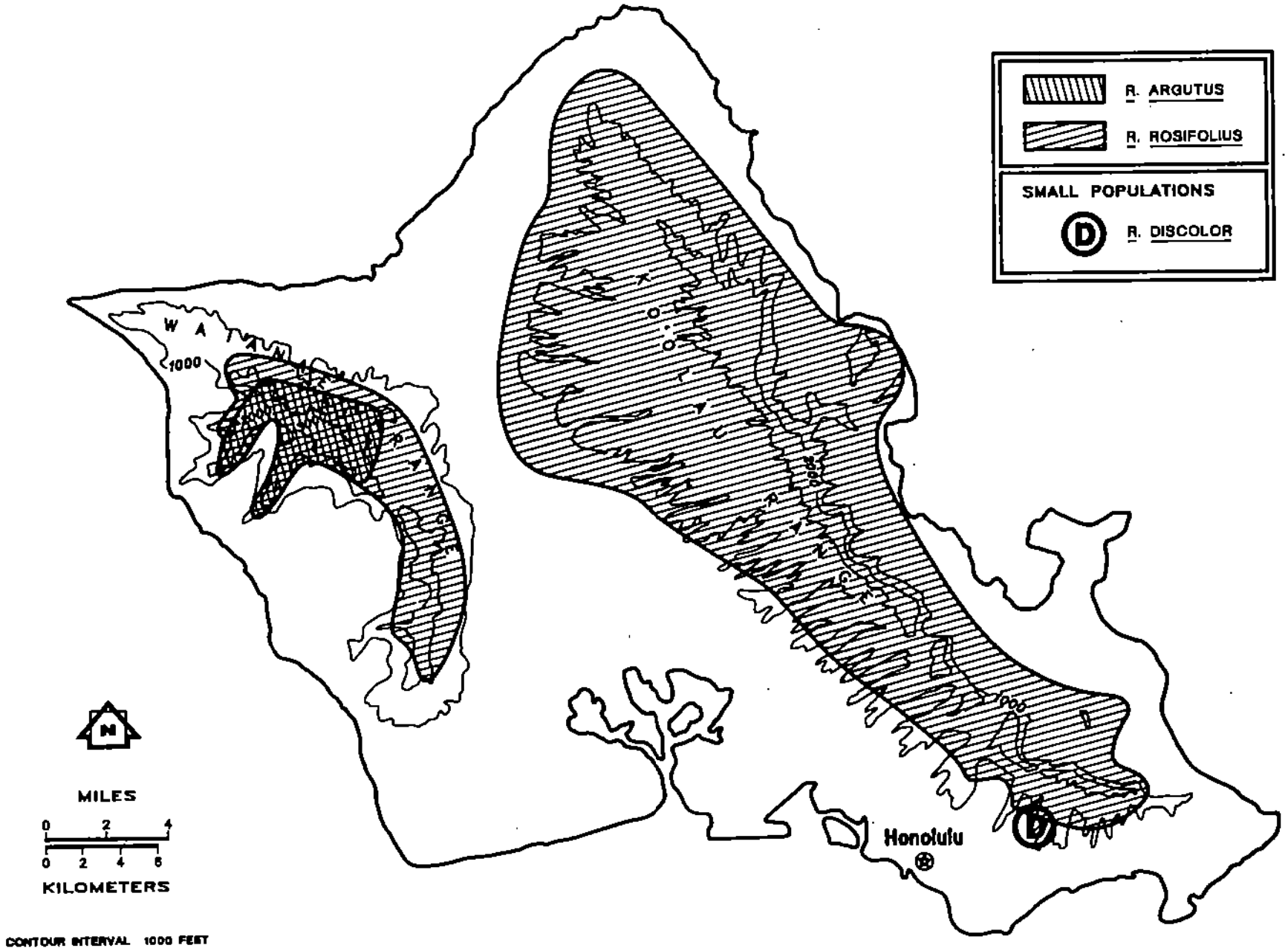


Figure 12. The range of the endemic Rubus hawaiiensis on the island of Kaua'i.

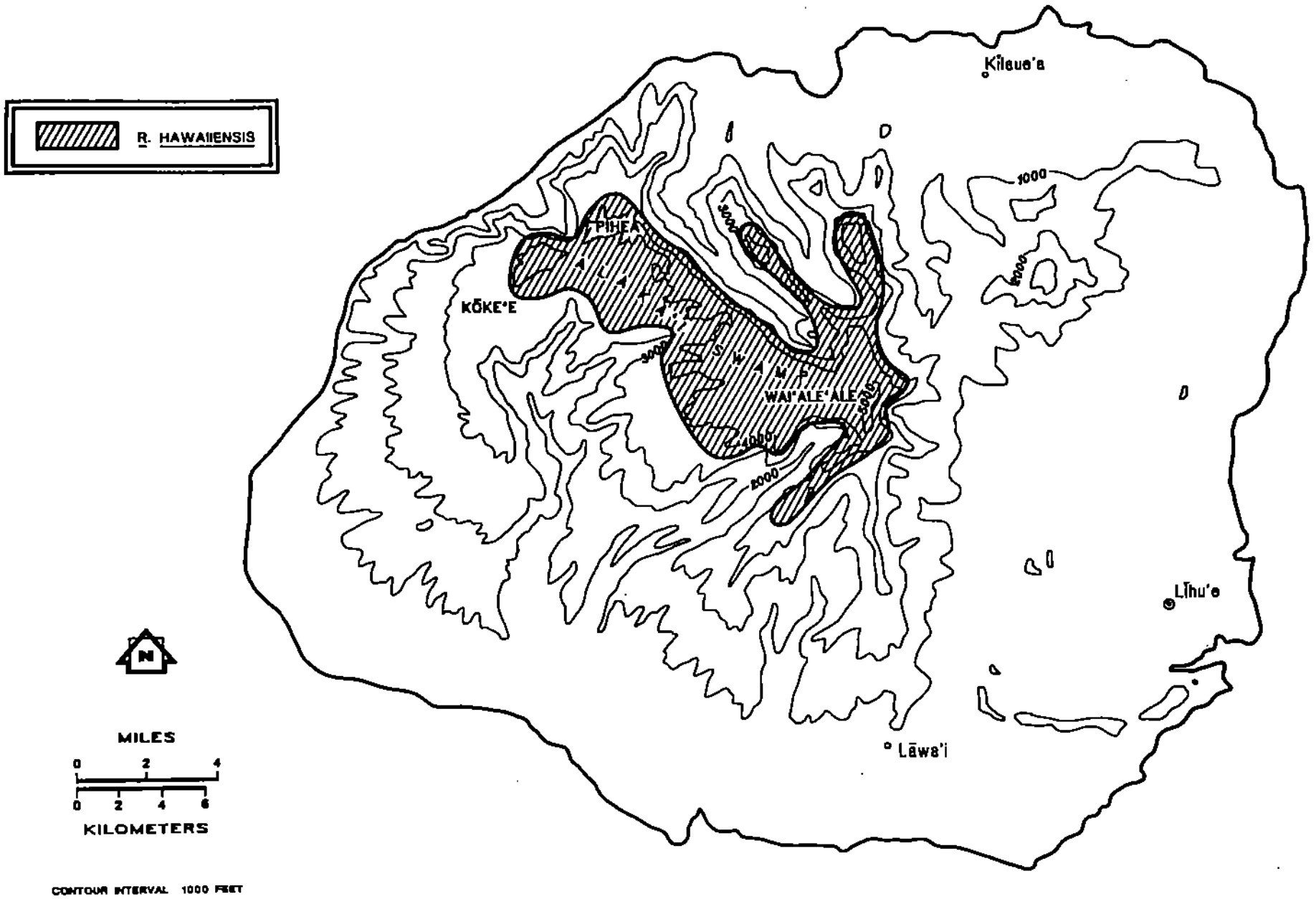


Figure 13. The ranges of three alien Rubus species, R. argutus, R. rosifolius and R. sieboldii, on the island of Kaua'i.